

Understanding the Global 3D Signature of Tree Biodiversity

ATTICUS STOVALL

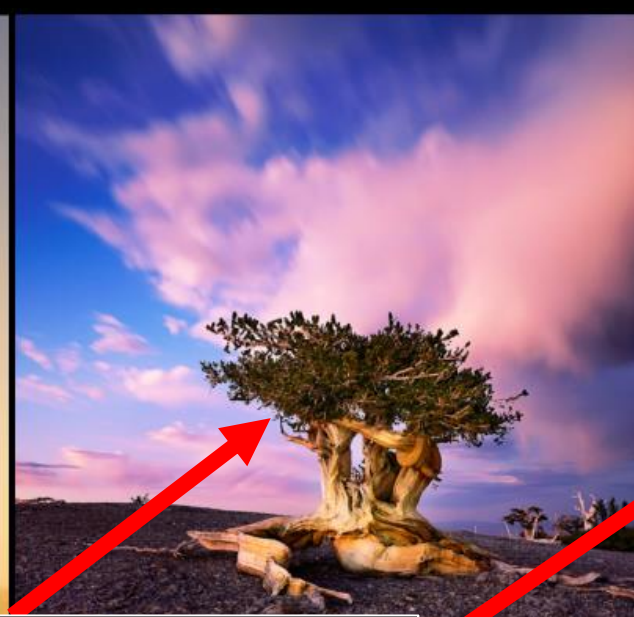
Science PI
UMD / NASA GSFC

Co-Authors:

Lola Fatoyinbo, John Armston, Kim Calders Lisa Bentley, Mat Disney, Shukhrat Shokirov

email: atticus.stovall@nasa.gov
Twitter: @StovallAtticus





Tree structure is extremely diverse



How do we quantify the structural traits of biodiversity?



Terrestrial laser scanning brings 3D to biodiversity traits



*Goal: Better understand the **structural and functional scaling relationships of trees** by quantifying drivers of tree-level traits for improved characterization of **biodiversity**.*

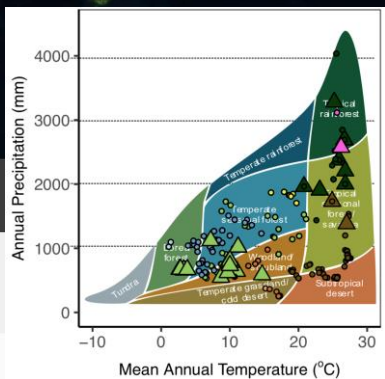
- 1) Develop **global TLS database** and **extract 3D traits**.
- 2) Validate and test **allometry** and **scaling theories**.
- 3) Link **scaling relationships** to **environmental conditions**.



TLS Network

- ☒ NASA CMS 3D Change
- ☒ TERN / JRSRP
- ☒ Ghent University
- ☒ University College London
- ☒ University of Virginia
- ☒ Wageningen University
- ☒ University of Helsinki
- ☒ University of Maryland
- ☒ National University of Comahue

Campaign Planning



University
Ghent University
BE_HI_T3

Ghent

Search:



We have assembled a
global dataset

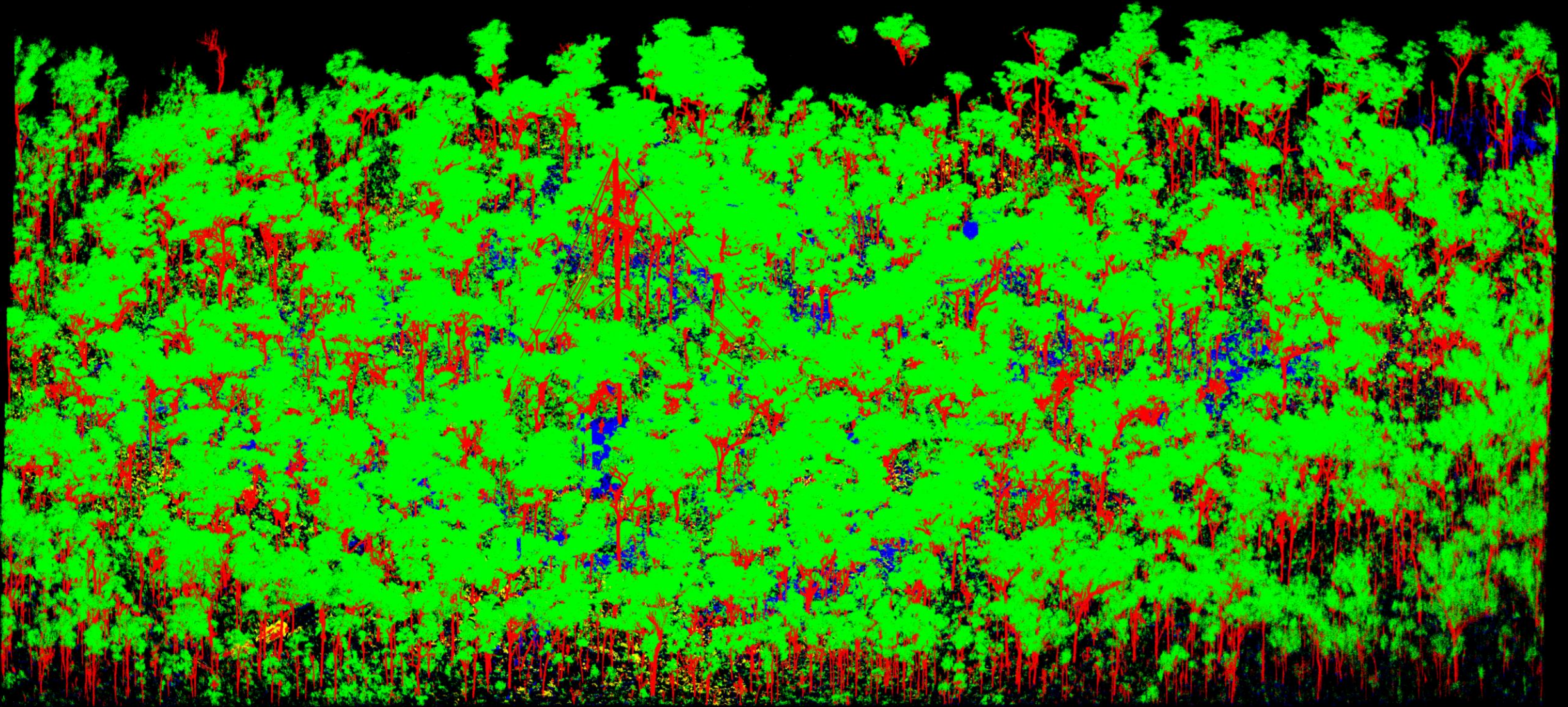
me	Datetime	Instrument	Protocol	Area	QSM	Open
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- 1st year grew by **106 TLS plots to 1108!**
- 57 members (47 with TLS data) and 40 institutions have joined
- Manuscript in-prep introducing TLS database

2018-07-	RIEGL	edge_core transect 100m 5scans	0.00	No	contact:kim.calders@ugent.be	Pieter DeFre
2018-07-	RIEGL					

Showing 1,070 plot scale acquisitions

Separating trees into Leaf and Wood



Separating trees into Individuals



Manuscript in-prep comparing 4 segmentation algorithms

Woody structure for architectural traits

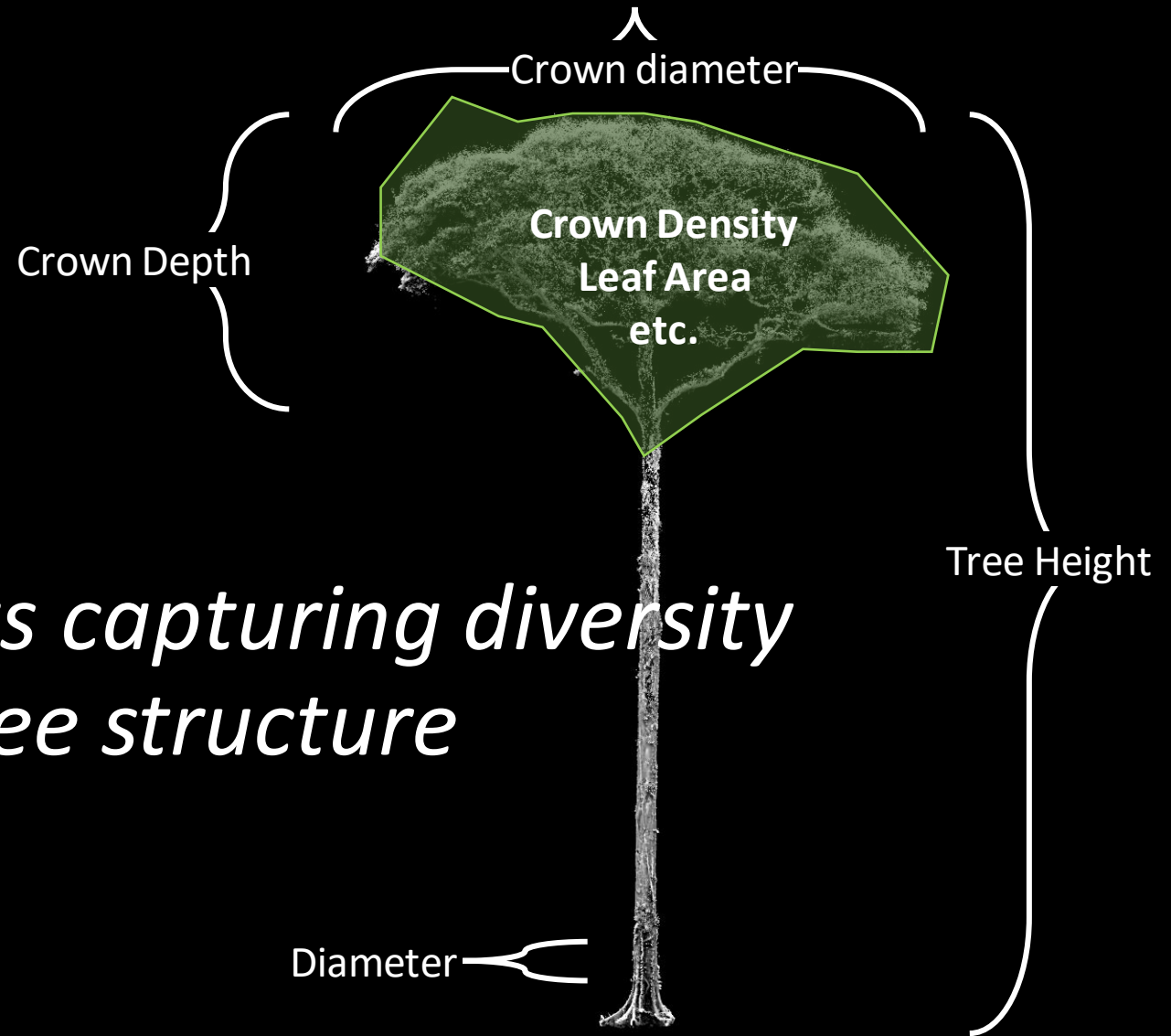


**20 newly processed plots in a
range of forest types
>10,000 newly segmented trees**

Tree-level Structural Biodiversity Traits (SBTs)

SBTs
Top-heaviness
Aspect ratio
Relative Crown Width
Crown Area
Leaf Area
Crown Density
Mass Taper Exponent
Path Fraction
Crown Asymmetry
Branching Angle

*Traits capturing diversity
of tree structure*



We are developing a standardized processing framework for all Co-Is, Collaborators, and GTLS members to apply



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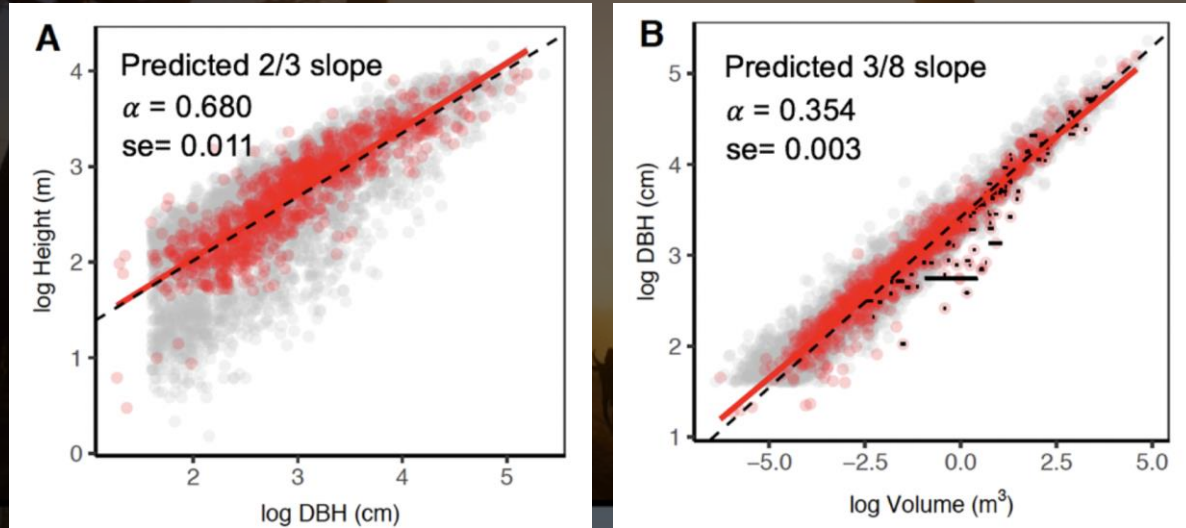
Campaign Planning



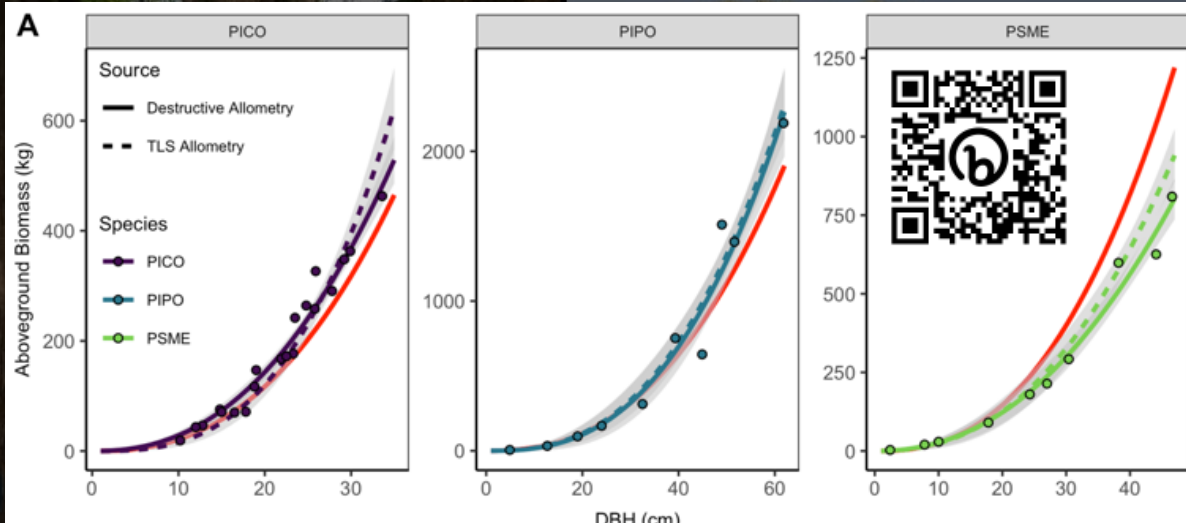
Actively planning S. Africa field campaign in Kruger NP

Group	Name	Datetime	Instrument	Protocol	Area	QSM	Open
Ghent University	BE_HI_T1	2018-07-04T00:00:00	RIEGL VZ400	edge_core_transect_100m_5scans	0.00	No	contact:kim.calders@ugent.be;Pieter.
Ghent University	BE_HI_T2	2018-07-04T00:00:00	RIEGL VZ400	edge_core_transect_100m_5scans	0.00	No	contact:kim.calders@ugent.be;Pieter.
Ghent University	BE_HI_T3	2018-07-04T00:00:00	RIEGL VZ400	edge_core_transect_100m_5scans	0.00	No	contact:kim.calders@ugent.be;Pieter.
Ghent	BE_HI_T4	2018-07-	RIEGL	edge_core_transect_100m_5scans	0.00	No	contact:kim.calders@ugent.be;Pieter.

2) We are beginning to validate local and national-scale allometry at study sites in the GTLS database.

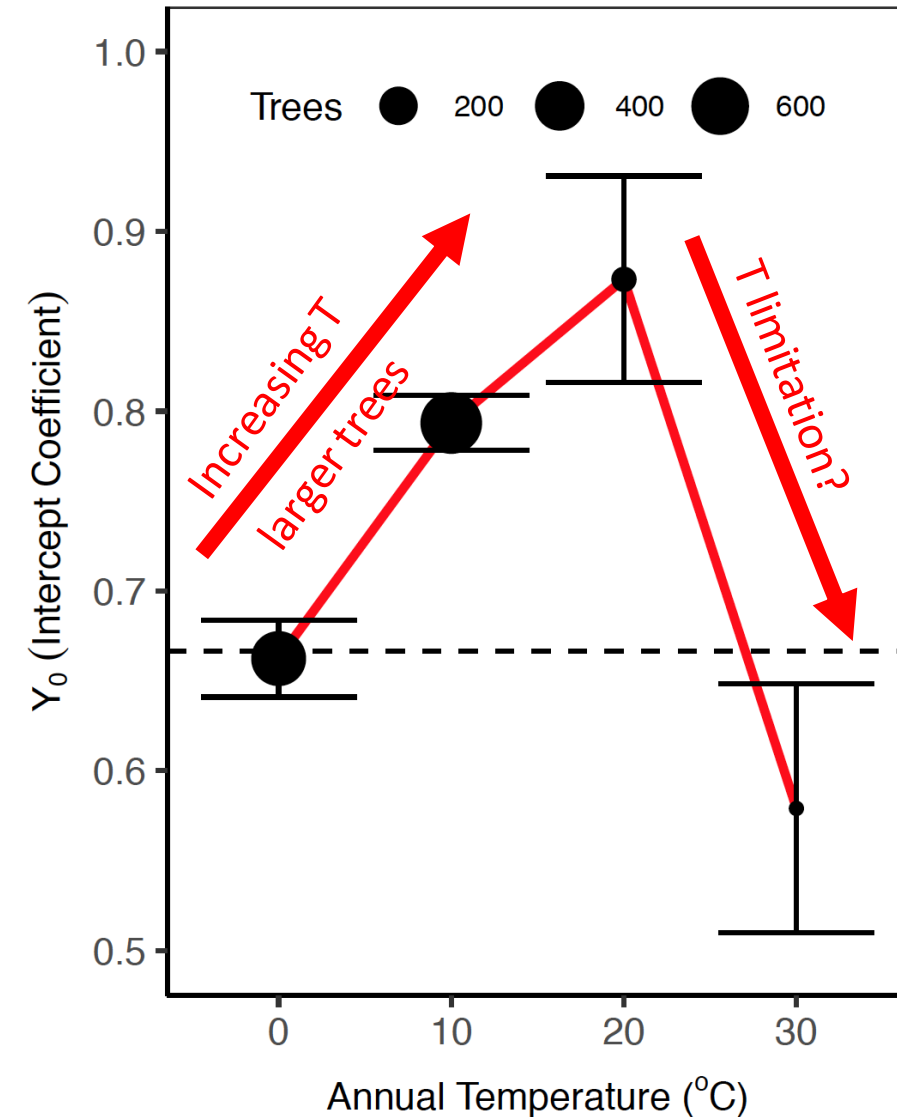
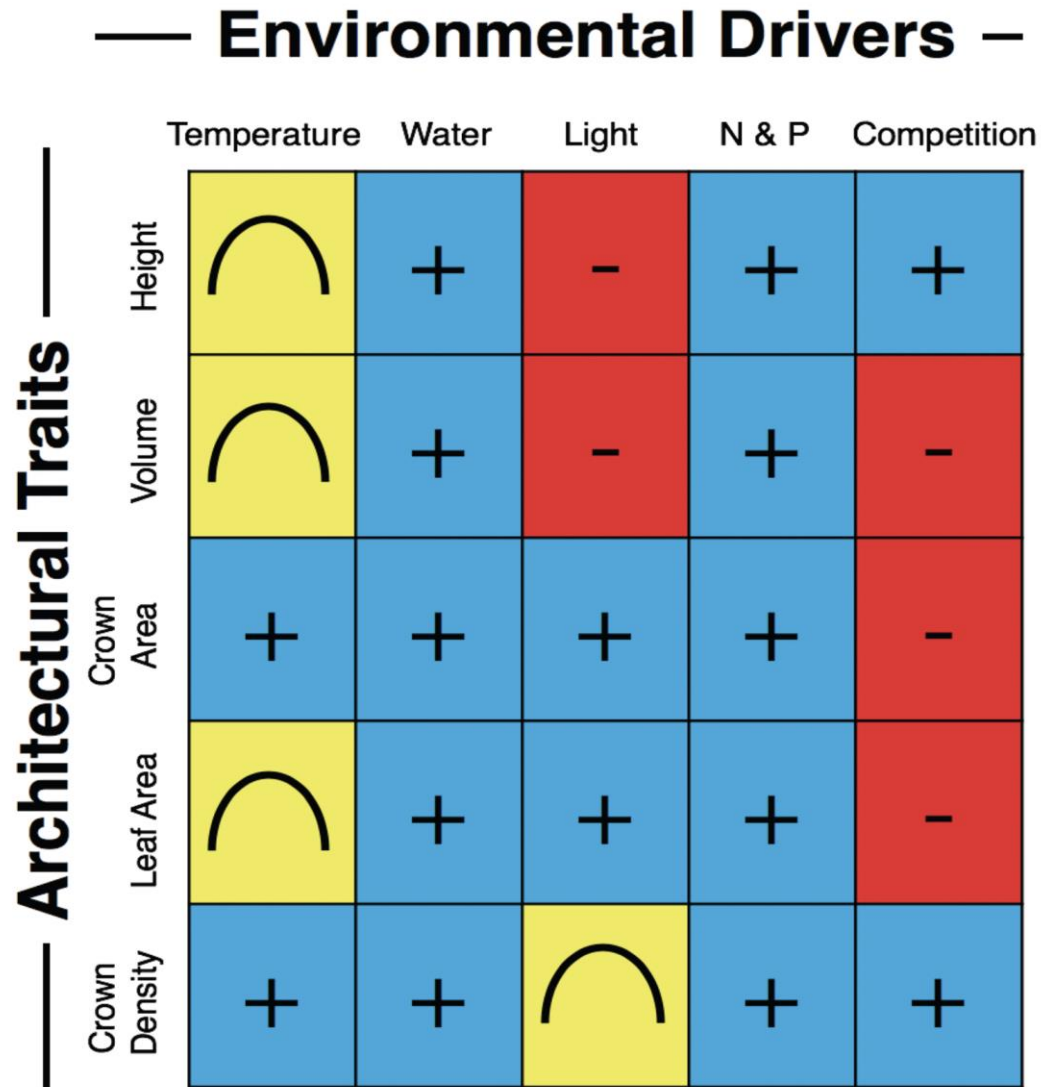


Test metabolic scaling theories (ongoing)



Validate Local and National Allometric Relationships (ongoing)

Link scaling relationships to environmental conditions.



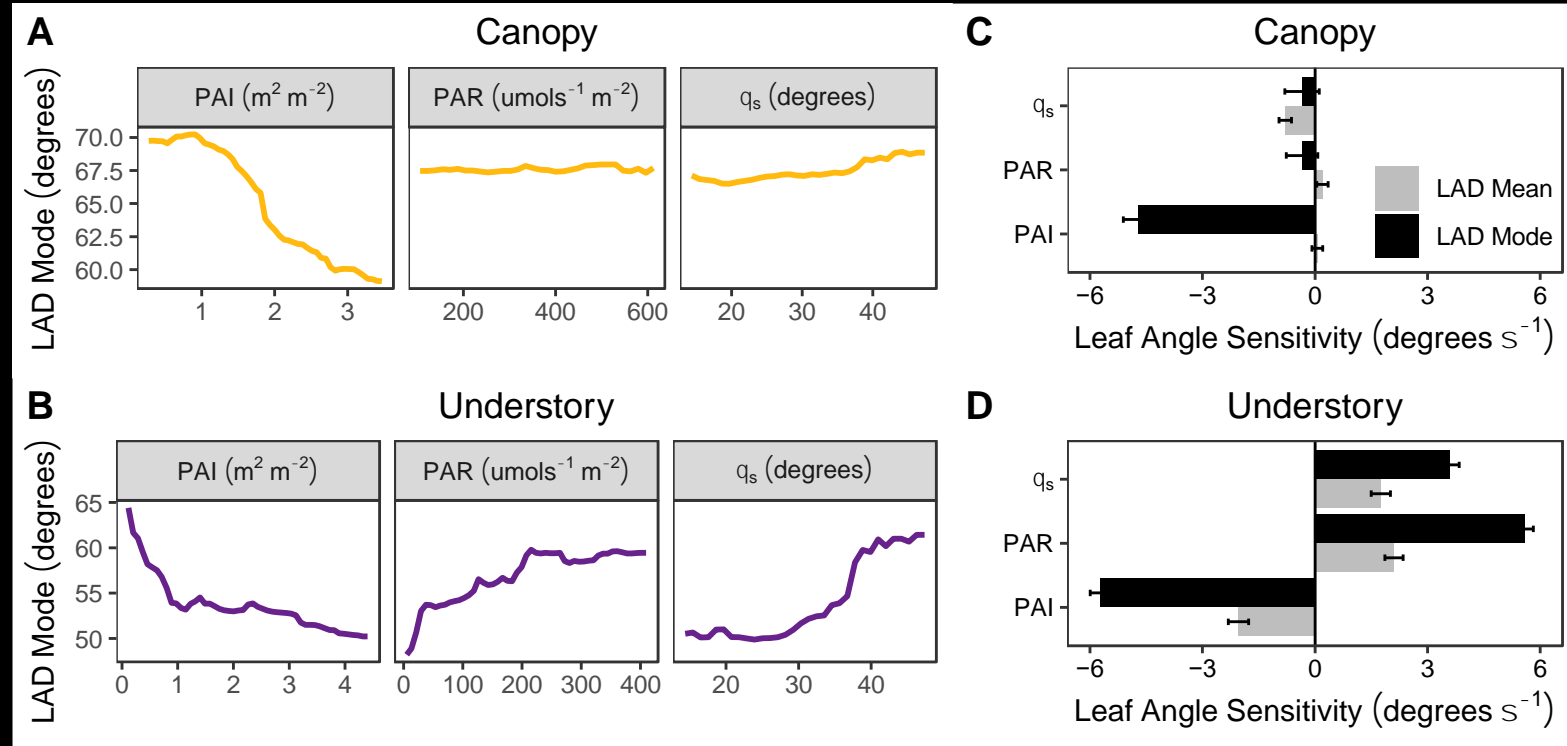
What environmental factors control leaf angle?

3 manuscripts focusing on leaf angle as a new measurable structural biodiversity trait



Stovall AEL, ..Fatoyinbo L, Yang X (2021) New Phytologist. doi:10.1111/nph.17548

Yang X, Li R, Jablonski A, et al (2023) Ecology Letters: doi: 10.1111/ele.14215

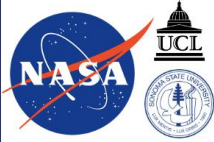


Sensitivity of [A] canopy and [B] understory leaf angle mode (the most commonly observed leaf angle) to seasonal shifts in plant area index (PAI), photosynthetically active radiation (PAR), and solar inclination angle (θ_s).

Stovall et al. Submitted to *New Phytologist*

For more, chat with us at the poster session!

Understanding the Global 3D Signature of Tree Biodiversity



Atticus E.L. Stovall, Lola Fatoyinbo, John Armston, Shukhrat Shokirov, Lisa Patrick Bentley, Kim Calders, Mat Disney



Leaves and wood are classified, and trees are prepared for extraction of 3D biodiversity traits.

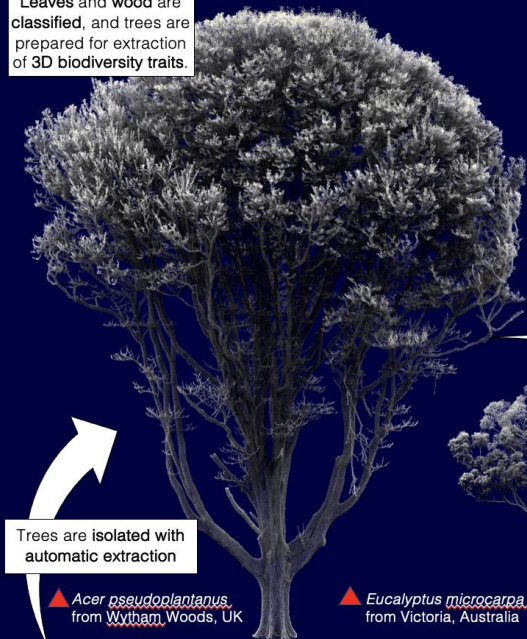
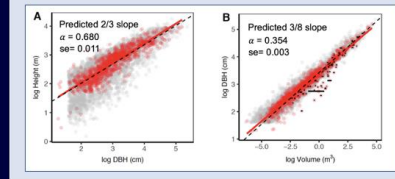


Table 1: 3D architecture structural biodiversity traits we will investigate to improve scaling theory.

Structural Biodiversity Traits	Description
Top-heaviness	Ratio of total woody volume in the crown to the stem woody volume
Aspect ratio	Ratio of maximum crown width to crown height
Relative Crown Width	Ratio of maximum crown width to tree height
Crown Area	Maximum ground area covered by the crown viewed from above
Leaf Area	Total tree leaf area
Crown Density	Ratio of crown area to woody volume in the crown
Mass Taper Exponent	Exponent of a power law fit to the vertical profile of volume
Path Fraction	Ratio of mean to maximum base-to-twig path length
Crown Asymmetry	The ratio of maximum to mean of 8 angular crown segments
Branching Angle	The average angle between two cylinders at each branching point

3D biodiversity traits help us understand scaling in trees



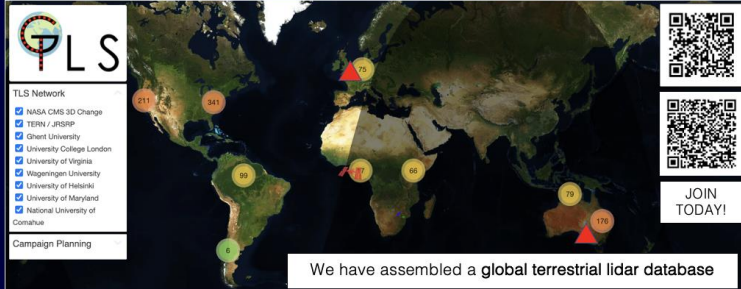
How does environment control scaling relationships?

Environmental Drivers

	Temperature	Water	Light	N & P	Competition
Height	+	+	-	+	+
Volume	+	+	-	+	-
Crown Area	+	+	+	+	-
Leaf Area	+	+	+	+	-
Crown Density	+	+	+	+	+

Contributions from international collaborators are making the TLS database grow!

Trees are isolated with automatic extraction



We have assembled a global terrestrial lidar database

BioREaCH Biodiversity-Remote sensing for Estuarine and Coastal Habitat research

Anthony Campbell^{1,2}, Daniel Jensen³, Atticus Stovall^{1,4}, Elhadi Adam⁵, Marc Simard³, and Lola Fatoyinbo¹

¹Goddard Space Flight Center, ²University of Maryland Baltimore County, ³Caltech/Jet Propulsion Laboratory ⁴University of Maryland, ⁵University of the Witwatersrand



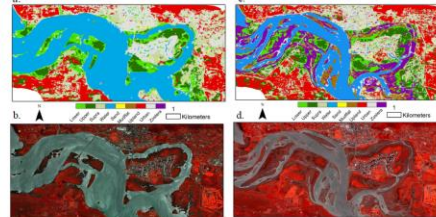
Year One...

We focused on six of our nine tasks during the first year of our project, including planning field data collection, prediction of plant function types, calculating spectral diversity and dimensionality, expanding to space-borne data, time series analysis, and predicting climate impacts.

Prediction of Plant function types

We predicted estuarine plant functional type communities across the tidal gradient. We utilized high spatial resolution satellite data from Worldview-2/3. Here we highlight the result for the Knysna estuary (Figure 1). In Knysna, we mapped 366.5 ha of Zostera (Fig. 1c), a very similar amount of Zostera as previous estimates from the 2000s, i.e., 350-390 ha (Barnes and Elwood 2012). When repeating our classification for earlier years, we found that a higher tidal stage and turbidity made mapping Zostera extent impossible (Fig. 1a-b). However, the low marsh plant functional community was still mappable, though darkening was evident (Fig. 1. a-b).

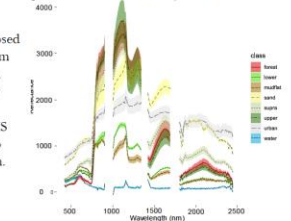
Figure 1. map and underlying data in pseudo color for December 2011 (a and c) and December 2021 (b and d). a and c represent a high tidal stage approximately 1.5 m above MLLW and b and d represent approximately 0.53 m above MLLW



Spectroscopy

In Knysna, we have explored the spectral separability of our proposed PFTs with EnMap at 30 m spatial resolution (Fig. 1). We further analyzed how these classes relate to elevation and expect LVIS or other elevation data to improve the classification.

Figure 2. EnMap spectral curves for major PFTs in Knysna estuary, South Africa. Each PFT had a minimum of three 30 m pixels selected which fell entirely within the PFT zone.



Change analysis

We have conducted preliminary change estimates for Knysna, Langbaan and a denser time series for Vedorenvlei. Our change analysis of Vedorenvlei demonstrates loss in water over the years from 1086 ha to 119 ha (Figure 3). A major drop in water extent was observed between 2010 and 2018 (Figure 3 c). We have also conducted time series trends for climate variables which will be used to model the future of these systems along with regional sea level rise rates. These changes are resulting in shifts to the marsh PFTs and risk biodiversity loss.

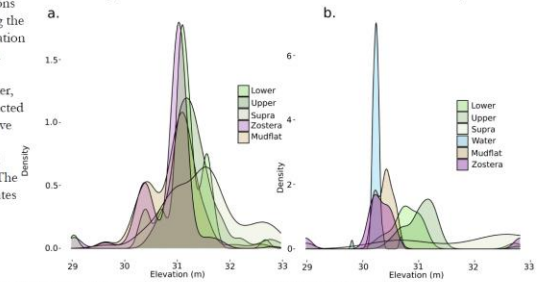
Planning - Field data collection

Our exploration of the existing spaceborne data streams and data fusion between lidar and space-borne spectroscopy demonstrates that the BioScaPES aerial campaign will offer unique data to improve classification and answer our overarching hypotheses surrounding biodiversity across the estuarine gradient. We plan to use these maps to inform field data collection. Tidal stage exploration demonstrates the potential impacts on extent mapping but can be quantified and controlled for with repeat high-resolution data mapping.

Estuarine gradients

We examine how our classifications relate to elevation and tides using the ICESat-2. We estimated the elevation of our estuarine PFTs (Fig. 4). In Knysna, we see little separability between classes (Fig. 4a). However, when considering lidar data collected at a low tidal stage (~0.30 m above MLLW), in this case, we can differentiate between the ground elevation of our PFTs (Fig. 4b). The elevation analysis also demonstrates that near MLLW tidal stage is necessary to map the exposed seagrass extent.

Figure 4. a. An example of a high tidal stage in the Knysna estuary resulting in a similar elevation corresponding with the tidal stage across all the plant functional communities. b. A lower tidal stage but similar to figure 2. a-c where Zostera is inundated but other tidal communities are exposed.



Barnes, R.S.K. and Elwood, M.F., 2012. Spatial variation in the macrobenthic assemblages of intertidal seagrass along the long axis of an estuary. Estuarine, Coastal and Shelf Science, 112, pp.173-182.

Tuesday and Thursday Afternoon

Thanks to all current contributors:

NASA GSFC

Terrestrial Ecosystem Research Network

University College London

University of Virginia

University of Nevada Reno

Wageningen University

We look forward to more!



For more information, contact:
Atticus.E.Stovall@NASA.gov



Sign up!



GTLS Map

